Thomas Wetland Summer 2004 Temperatures
Technical Report

Clark County Public Works
Water Resources Section

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Introduction

This technical report summarizes Clark County Water Resources' monitoring of water and air temperatures at the Thomas Wetland mitigation site and vicinity during the summer of 2004. The Thomas Wetland site was enhanced primarily to help mitigate road construction impacts to wetlands elsewhere within the Burnt Bridge Creek watershed. Specifically, the Thomas Wetland project was designed to enhance the hydrologic, water quality treatment, and habitat functions of a degraded wetland and pasture (Clark County Dept. of Public Works, June 18, 2002). This preliminary temperature monitoring project provides baseline information for possible future efforts to track the site's potential water quality benefits or impacts as well as provides insight for the design of other similar projects.

Site characteristics will change over time from those created by the relatively recent construction and enhancement activities (Figure 1). Substantial regrading of much of the site was one of the initial site mitigation activities in the fall of 2003 (Christian, 2003). Early wetland mitigation monitoring shows progress on: the establishment of an adequate hydrologic regime, survival of phased native species plantings, maturing canopy expansion, and weed control (Christian, 2004). However, as often is the case, the potential benefits from the Thomas Wetland mitigation are expected to change over time as the site matures; necessitating ongoing management and periodic monitoring.

Purpose

The purpose of this preliminary monitoring effort is to evaluate the potential impacts of the Thomas Wetland site on water temperatures of the St. Johns subbasin stormwater system. This information will provide baseline information and help determine the need for potential follow-up monitoring as well as future management options that could mitigate possible temperature impacts.

Study Area / Site Characteristics

The recently enhanced Thomas Wetland is located in unincorporated southwest Clark County, Washington (Figure 2). More specifically, it is northeast of the City of Vancouver between NE 51st and NE 54th Streets and east of NE 40th Avenue. The Thomas Wetland is contained within the St. Johns subbasin whose western boundary lies within the City of Vancouver but is mostly to the northeast in the unincorporated area of Clark County. The St. Johns subbasin is a subwatershed of the Burnt Bridge Creek watershed of southern Clark County.

The Thomas Wetland site and vicinity is characterized by a mixture of suburbanizing land uses overlying the area's rolling topography and stormwater system. Clark County owns and maintains the 10.92 acres of open space encompassing Thomas Wetland (Clark County Department of Public Works, June 18, 2002). However, the site is mostly surrounded by increasing suburban development (Figure 2). There are 290 acres of

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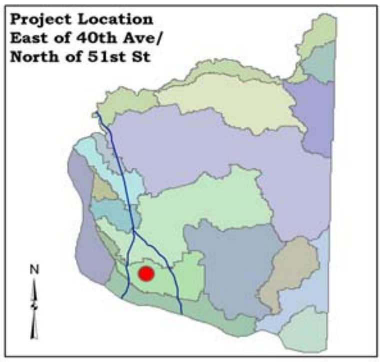

Prior to construction.

During construction.

Shortly after construction and hydroseeding.

In operation. Plants getting established.

proud past, promising future
CLARK COUNTY
WASHINGTON

Figure 1 Thomas Wetland Construction and Plant Establishment.

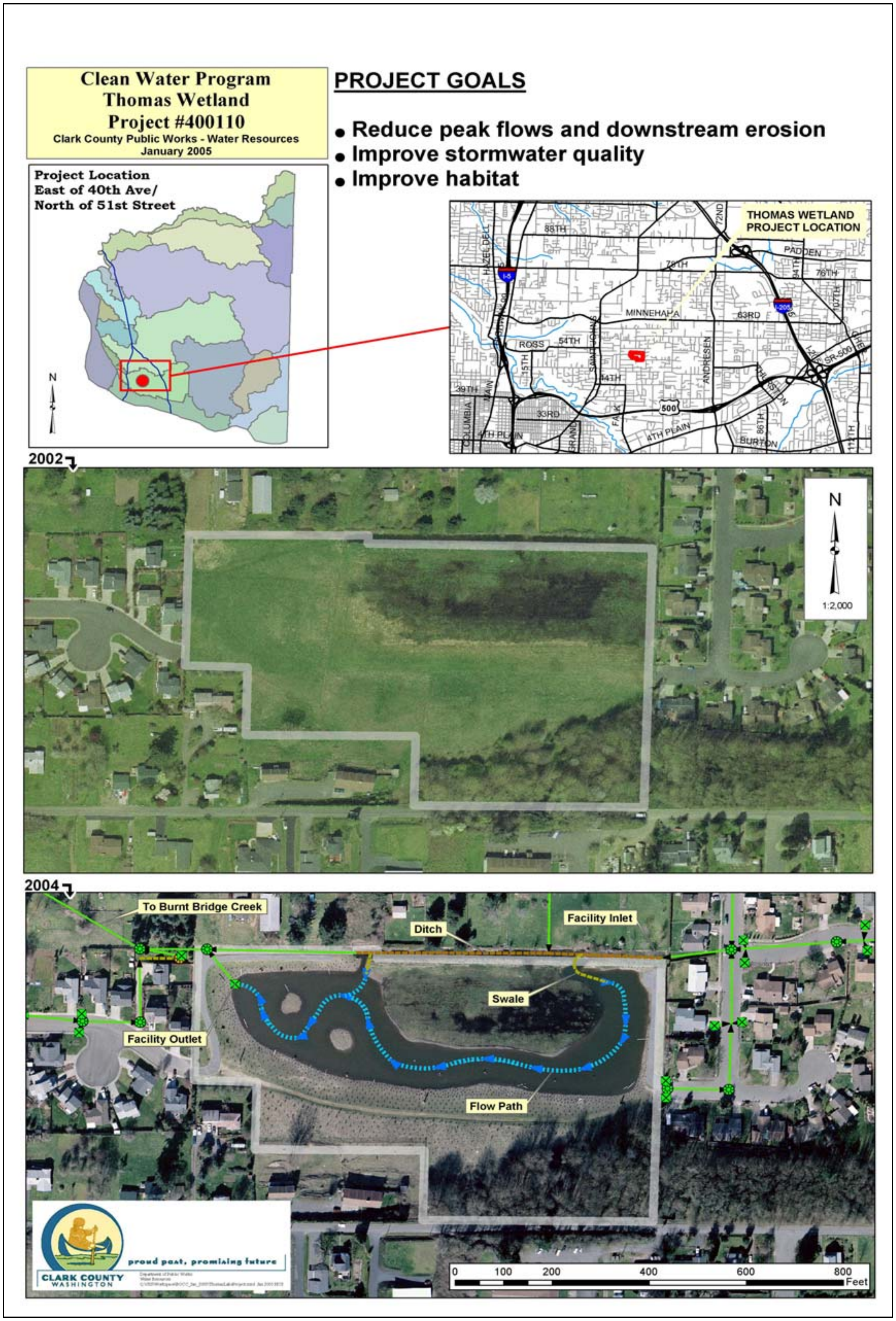

Figure 2 Vicinity Map and 2002 versus 2004 Aerial Images of Thomas Wetland.

residential subdivisions and open fields that drain into Thomas Wetland through a system of ditches and storm sewers. Most of the surface flow entering the wetland is through a concrete pipe inlet at the property's northeast corner after passes under 53rd Circle and NE 48th Avenue. Water is also contributed to the wetland by shallow groundwater discharge along the base of the steep slope to the south of the wetland (Figure 3). Flows exit through the outlet on the northwest side of Thomas Wetland then are piped approximately 1.5 miles through a stormwater system to an outflow into Burnt Bridge Creek at the intersection of St. Johns Road and Arnold Road.

As part of the Thomas Wetland enhancement, regrading of the site in 2003 was also intended to optimize hydrologic, water quality, and habitat conditions (Clark County Department of Public Works, June 18, 2002). Much of the wetland's higher flow water is diverted from the existing old ditch/channel into the regraded portion (Figure 2). High flows enter a deep water inlet cell for sedimentation and then slowly flow through deep water, emergent, and forested wetland components (Figure 3). This results in a much longer flow path and increased residence time for additional dissolved pollutant treatment via wetland filtration and plant uptake. Overall, the regraded area provides additional stormflow detention and peak flow reduction compared to the old straight channel / ditch along the wetland's northern border. Under low flow conditions, flows were designed to follow a meandering path through the wetland. The project also greatly increased and diversified wetland habitats that benefit species richness.

The mitigation site work resulted in approximately six acres of wetland creation, enhancement, preservation, and habitat improvements while also providing wetland mitigation credit. Most of this credit was applied to the NE 162nd Avenue widening project in the extreme eastern portion of the Burnt Bridge Creek watershed where Washington Department of Ecology mitigation required 5.81 acres of wetland mitigation in this watershed (Clark County Dept. of Public Works, June 19, 2002).

Methods / Quality Assurance

Seven Onset temperature loggers were deployed at multiple stations around Thomas Wetland and its vicinity (Table 1) to record temperature variation over the summer of 2004. Five loggers were deployed within the County property containing Thomas Wetland (Figure 3). Two additional loggers were also deployed within the St. Johns subbasin stormwater system in the vicinity of Thomas Wetland to track temperatures of an adjacent catchment and those downstream at the basin outflow. These additional loggers were specifically located in manholes at the intersections of NE 44th Street / NE 39th Avenue and St. Johns Road / Arnold Road respectively.

The procedures described in the project's Quality Assurance Project Plan were followed to ensure data accuracy and minimize bias (Clark County Public Works Water Resources, July 2004). All temperature loggers appeared to be operating at acceptable levels of accuracy. Pre and post deployment temperature comparisons with National Institute of Standards and Technology (NIST) traceable thermometers were acceptable.

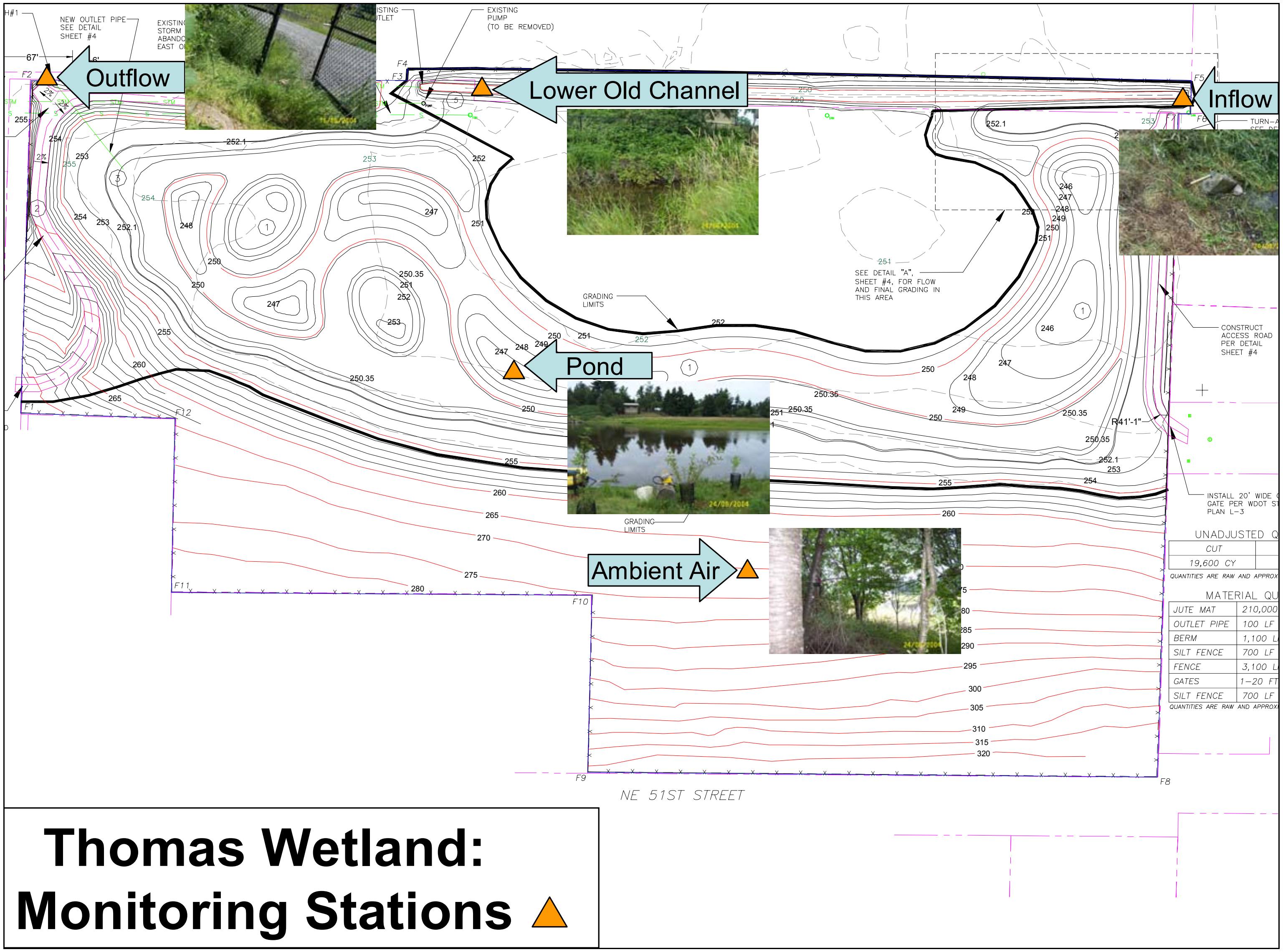

Figure 3 Thomas Wetland: Approximate Locations of Monitoring Stations.

Station Location Name	Logger Type	Deployment & Retrieval Dates	Estimated Variation in Relative Position (ft)	Comments
Ambient Air	H8	6/24/04 - 9/28/04	Constant: 7 ft above ground in tree	Suspended in forested shade
Inflow	Temp Pro	6/22/04 – 9/28/04	0.5 - 1.0 ft below water surface	1 ft out from end of inflow pipe
Lower Old Channel/Ditch	H8	6/24/04 – 9/28/04	0.5 - 1.5 ft below water surface	Suspended 2 ft from bottom of channel
Pond	H8	6/24/04 – 9/27/04	0.5 – 2 ft below water surface	Suspended 2.5 ft from pond bottom
Outflow	Temp Pro	6/22/04 – 9/28/04	0 – 0.5 ft below water surface	Suspended from manhole ladder rung
44th St & 39th Ave	Temp Pro	6/22/04 – 9/27/04	0 – 0.25 ft below water surface	Suspended from manhole ladder rung
St. Johns Rd. & Arnold Rd.	Temp Pro	6/22/04 – 9/28/04	0 – 1 ft below water surface	Suspended from manhole ladder rung

Table 1 Temperature Logger Deployment Site Characteristics.

A field temperature audit was conducted on August 12, 2004 with an YSI-85 multi-parameter field meter. The field audit showed that most of the stations were within 3 degrees F. of the YSI field temperature readings except for the Pond station. It was not possible to take a field reading at the exact location of the pond station due to water depth. Prior to the field audit measurements, the accuracy of the YSI-85 temperature readings was checked against a VWR thermometer that was traceable to the NIST. Initially, the probes' sensors were immersed into a 5 gallon bucket of water at room temperature. The NIST thermometer read 21.13 degrees Celsius versus a reading of 21.8 degrees Celsius for the YSI-85. This was followed by probe immersions in a refrigerated liter of water where the VWR NIST reading was 3.37 degrees Celsius versus 5.8 degrees Celsius for the YSI-85 after allowing the instrument sensors to equilibrate with their refrigerated baths. The precision of the readings was deemed adequate assuming slight heating of the limited refrigerated water volume and the relatively large mass of the YSI-85 probe.

Precipitation data from Clark County's Whatley Pit rain gauge, located approximately four miles to the northeast of the Thomas Wetland site, was also used for analysis. The originally recorded 15-minute increment totalized precipitation data was converted to hourly totals. The precipitation data was collected following standardized procedures (Clark County Public Works Water Resources, September 2003).

Results and Discussion

Overall Patterns

Overall, the monitoring stations' temperature readings display diurnal fluctuations to some extent and most have somewhat similar patterns over time (Figure 4). Both the currently applicable 1997 Washington State Class A 64.4 degrees Fahrenheit (F) temperature standard for Burnt Bridge Creek (Washington Department of Ecology, July 1 2003) and the 2003 proposed 7 Day Average Daily Maximum of 63.5 degrees F criteria (Washington Department of Ecology, August 2003) are superimposed on the time series for relative comparisons with station readings. The pond and ambient air stations had the highest temperatures and greatest daily variation. As might be expected, the shaded stations located in pipes, had considerably less variation and usually lower temperatures. With the exception of the pond outflow, all of the rest of the stations' temperature central tendencies and their daily fluctuations generally increased from June to the beginning and middle of August. After which they gradually decreased through the end of September. The diurnal temperature fluctuations of these remaining stations probably are driven primarily either by changes in direct solar radiation or indirectly through changes in the conduction of heat through water or air. In addition to rising ambient air temperatures, these increases for the submerged monitoring stations can also be attributed to a reduction in overlying water as Thomas Wetland's surface water level dropped. The wetland's summer water surface dropped 2 feet from about 252 to 250 feet above mean sea level, reducing the pond's area from approximately 3.2 to 1.4 acres (Figure 5).

The opposite temperature pattern for the pond's outflow station probably is driven by the gradual reduction and eventual lack of flow from the pond (Figure 6). Its temperatures reflect the more constant ambient ground temperature from mid-July to mid-August.

The periodic drops in temperatures across multiple stations probably result from sporadic rainfall events. Some of the smaller events may have missed the Whatley Pit rain gauge and thus are not displayed as Prior Hour Precipitation. The larger summer events probably directly cooled water surfaces via cooler precipitation and less solar heating due to cloudiness. However, these larger storms sometimes initially contributed relatively warmer waters to the stormwater systems, possibly due to contact with warmer impervious material such as pavement. These rain event temperature responses are most dramatically displayed during the August 19–28, 2004 period (Figure 7). Especially after these larger events the temperature profiles initially converged as the stormwater acted as an overall moderator of temperatures throughout the system. However, these rainy days' surface runoff also probably increased the piped stormwater temperature variability.

Individual Stations Temperature Patterns:

Ambient Air

As expected, the ambient air has much wider daily temperature fluctuations than the other stations. This is due to both its lower specific heat compared to water and that the ambient air station was more exposed to direct heat exchange via warm and cool winds than the other stations even though it was located in a tree shaded location.

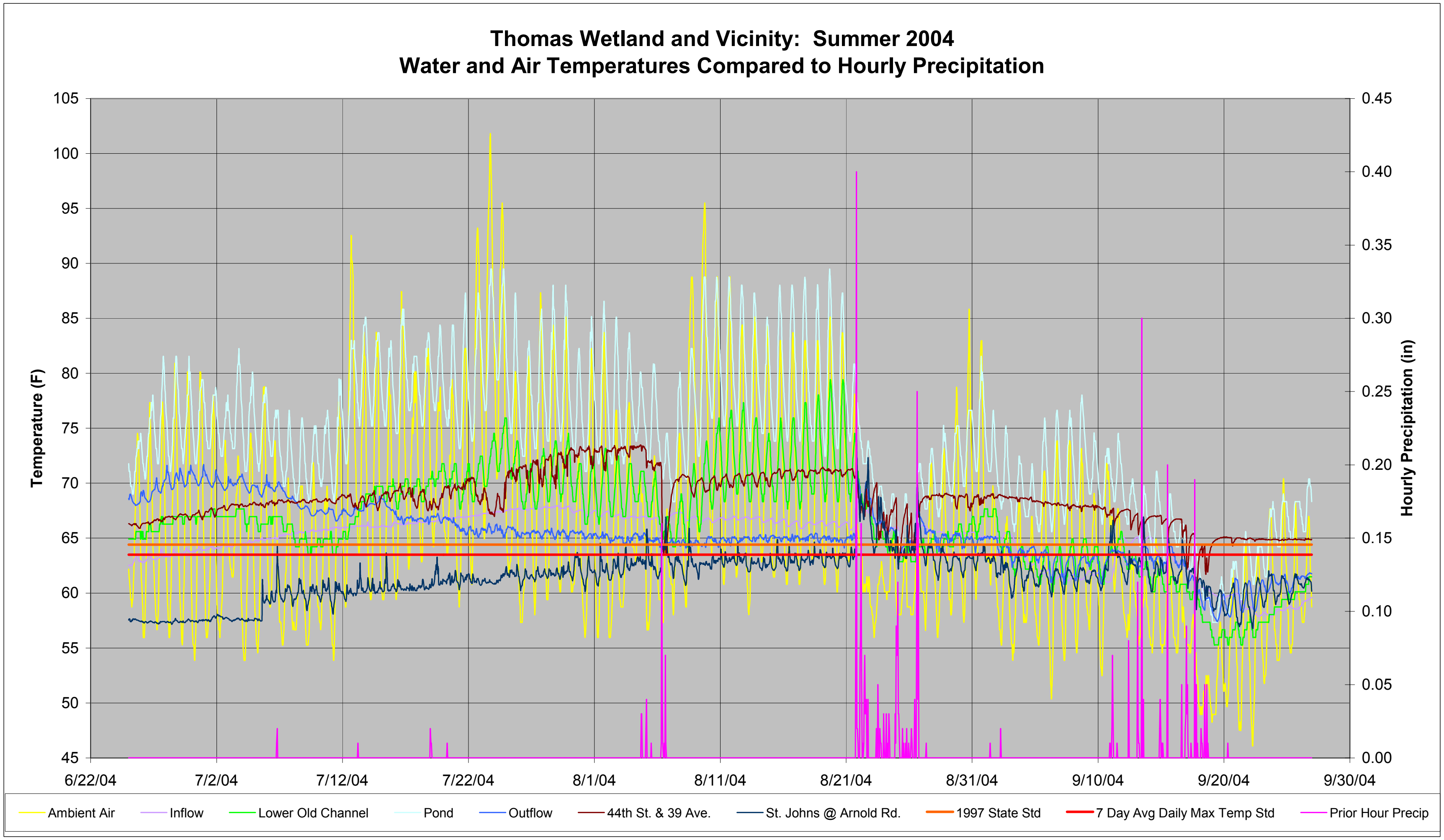

Figure 4 Thomas Wetland and Vicinity: Summer 2004 Water and Air Temperatures Compared to Hourly Precipitation.

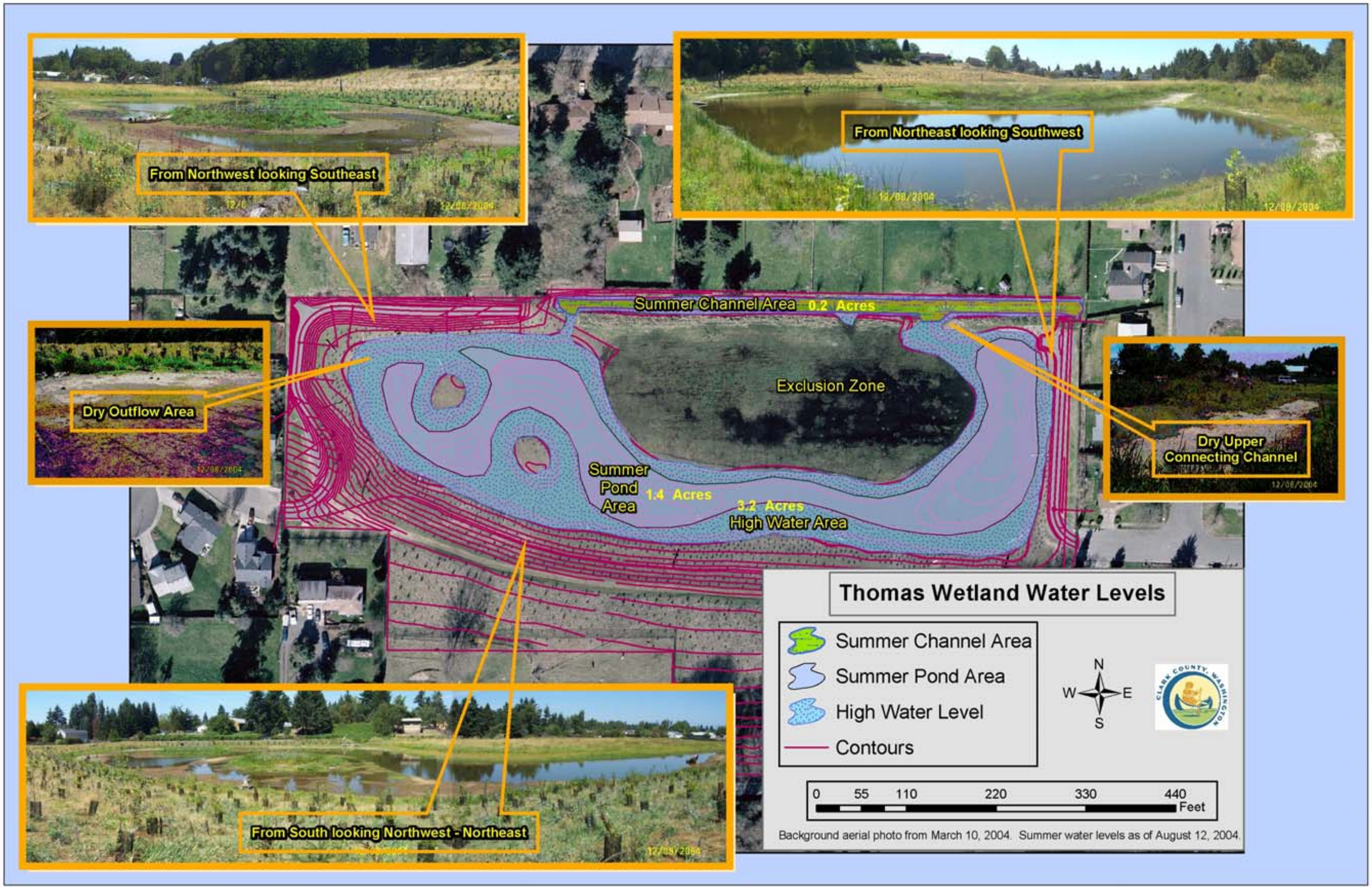

Figure 5 Thomas Wetland Water Levels.

Figure 6 Thomas Wetland Outflow After Construction and Summer 2004 Drop in Water Surface.

Event Periods Examined In Detail for Thomas Wetland Summer 2004 Temperature Time Series

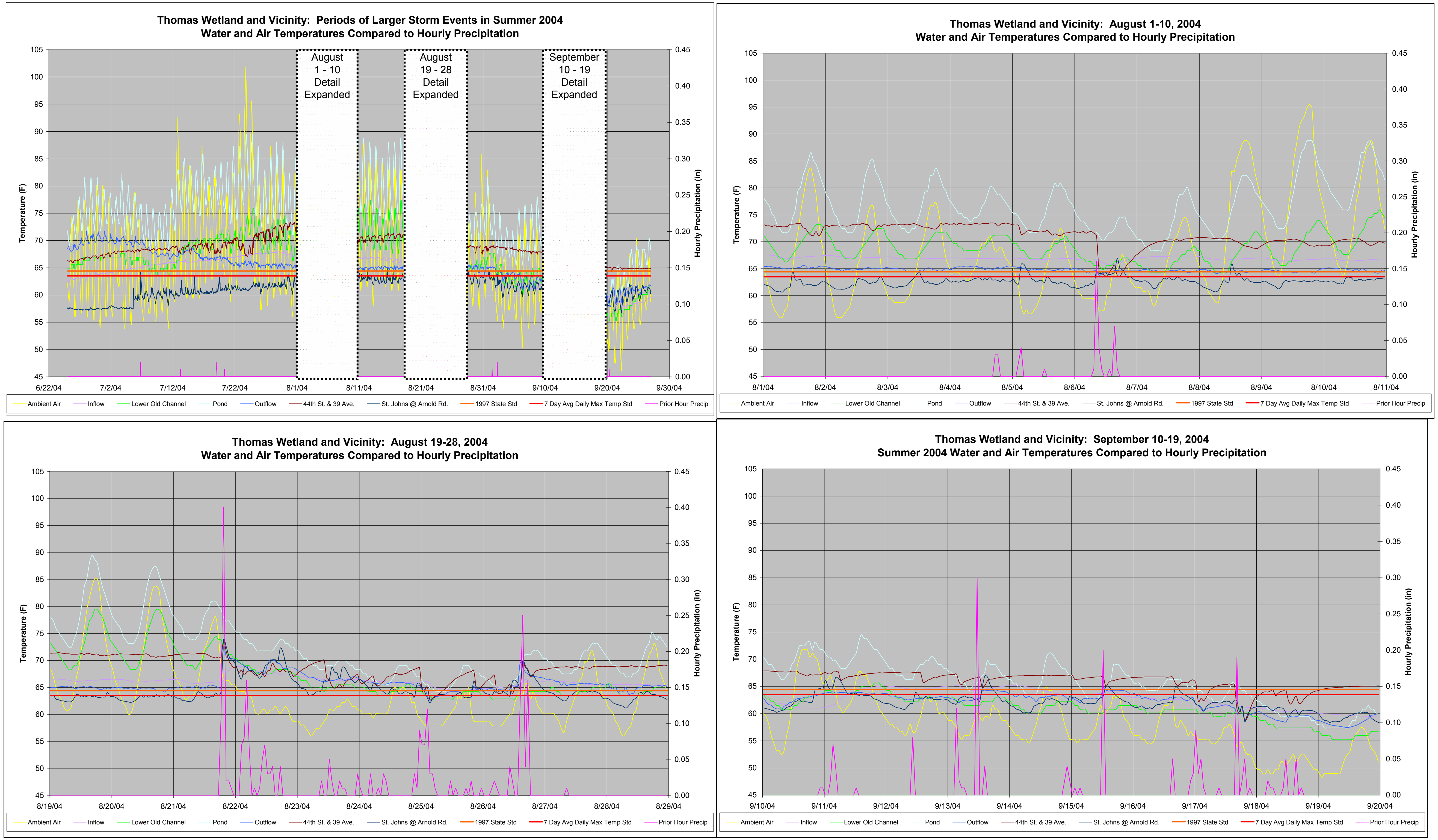

Figure 7 Larger Summer 2004 Rainfall Events for Thomas Wetland Temperature Time Series.

Inflow

The inflow's very gradual and moderated temperature increase, which levels off during mid summer, probably reflects impacts from ground temperatures and shading of the 100 plus feet of piped flow immediately upstream of the inflow station. Additionally, the day-lighted flow upstream of this pipe is still somewhat shaded by extensive, dense stands of Reed Canary grass that drain large wet areas.

Lower Old Channel

The lower old channel generally parallels the pond's temperature pattern through mid-July but typically its daily maximum temperatures were 5 degrees F cooler than even the pond's minimum daily temperatures. During the more intense summer heating period from mid-July through mid August, the old channel's daily temperatures fluctuated much more widely and became more similar to those of the pond's temperatures while still remaining cooler. The mid-summer pattern may also partly result from the overall drop in the pond's surface during the dry mid-summer period. This could have resulted in the lower old channel temperature logger being closer to the water surface and temperatures more similar to those of the open water pond station. The temperature pattern for the heavily vegetated lower old channel may resemble future patterns in the wetland's ponds as more submerged and emergent wetland plants become established as the site matures.

Pond

Excluding rainy periods, the pond's temperatures were much warmer than those for any other water monitoring sites. Additionally, daily pond temperature maximums often exceeded ambient air temperature maximums. These warmer temperatures could be impacted by the large area of direct sunlight exposure on the pond's surface. Conversely, the ambient air temperature probe's location was seven feet above the ground in a grove of trees with a northern aspect. As noted above, probably the peak daily pond temperatures are also impacted by the gradual dropping in the pond's depth. This resulted in a reduction of the pond temperature recorder's depth from the surface from approximately 2 feet to possibly less than 0.5 feet during the mid-summer.

Outflow

As noted above, the only exception to the generally increasing temperature pattern was for the outflow station. At this station the apparent drop in temperatures during the first half of the summer probably reflect very little to no flow through the outflow pipe and represent more of the ambient ground temperatures.

St Johns Rd at Arnolds Rd. and 44^{th} St. / 39^{th} Ave Manhole Sites

The temperature loggers located in the manhole stations (i.e., 44^{th} St. / 39^{th} Ave and the St. Johns Rd. at Arnold Rd.), which when removed on September 27 and 28 were lodged above the water surfaces in the pipes by earlier high water flows, reflect a combination of stormwater flow and ambient air temperatures in the stormwater pipes. Typically the St Johns manhole station had consistently cooler summer temperatures than any of the other stations. This could be the result of year-round cooler groundwater contributing a larger proportion of its flow during the drier periods of summer and cooling due to heat exchange with relatively colder soils around stormwater pipes. Even after the probe was deposited just above the fast flowing water surface in the steeply sloping stormwater pipe, the monitored temperature of the ambient air in the pipe probably approached that of the water due to nearby droplets spraying into the air from small obstructions in the pipe's fast flow. This contrasts with the much smaller and warmer flow in the 44th St. / 39th Ave. manhole station where very little flow or stagnant flow occurred during the summer.

Prior Hour Precipitation

The Prior Hour Precip indicates the precipitation pattern at the Whatley Pit approximately 4 miles to the east of Thomas Wetland. Hourly rainfall amounts are indicated as vertical bars scaled along the time series graph's right y-axis. The period after the first small precipitation event during July appears to coincide with some subdued cooling of the ambient air, pond, lower old channel and the outflow stations but the impact from subsequent small July rainfall events was more subdued if at all. The larger precipitation events during early and late August as well as mid-September appear to have led to runoff entering the stormwater system and impacting the temperatures recorded at both the 44th St. / 39th Ave. and St. Johns Rd. at Arnold Rd. manhole stations. The pond's outflow temperature also appears to have been impacted by these later storm events but not the early August storms. Many of the mid-summer precipitation events do not appear to have been sufficient to raise the pond's volume to contribute to and substantially change the outflow temperatures.

Monitored Temperatures Compared to State Standards

Overall, except for the St. Johns subwatershed outfall station at St. Johns Road at Arnold Road, almost all of the water temperature monitoring stations' mid-summer values continuously exceeded the 1997 state standard until late in August. These same stations' mid-summer calculated 7-day average daily maximum water temperatures, again with the exception of St. Johns Rd. at Arnold Rd., also exceeded the proposed 7-day average daily maximum temperature criteria (Figure 8). The state's proposed 2003 7-day average daily maximum criteria of 63.5 degrees F for Burnt Bridge Creek (Washington Department of Ecology, August 2003) is superimposed on the stations' calculated 7-day average daily maximum time series for relative comparisons.

Water temperature stations only partially dropped below the maximum temperature standards after the sustained precipitation events in late August. After these sustained events some of the stations exceeded the temperature standards again during very late August and early September. After most of the stations' temperatures gradually dropped below the maximum temperature standards during mid-September storms, they finally dropped substantially into the non-exceedance range in late September. A similar, but more subdued, pattern occurred for the stations' calculated 7-day average daily maximum water temperatures when compared to the state's proposed criteria. Importantly, the only station exception to these typical temperature exceedance patterns was for St. Johns at Arnold Road which is the closest monitoring station to the stormwater system's outfall into Burnt Bridge Creek. Apparently, as noted earlier, cooling groundwater infiltration into the system and the surrounding cooler soil temperatures substantially mitigate this stormwater system's temperature impacts on Burnt Bridge Creek.

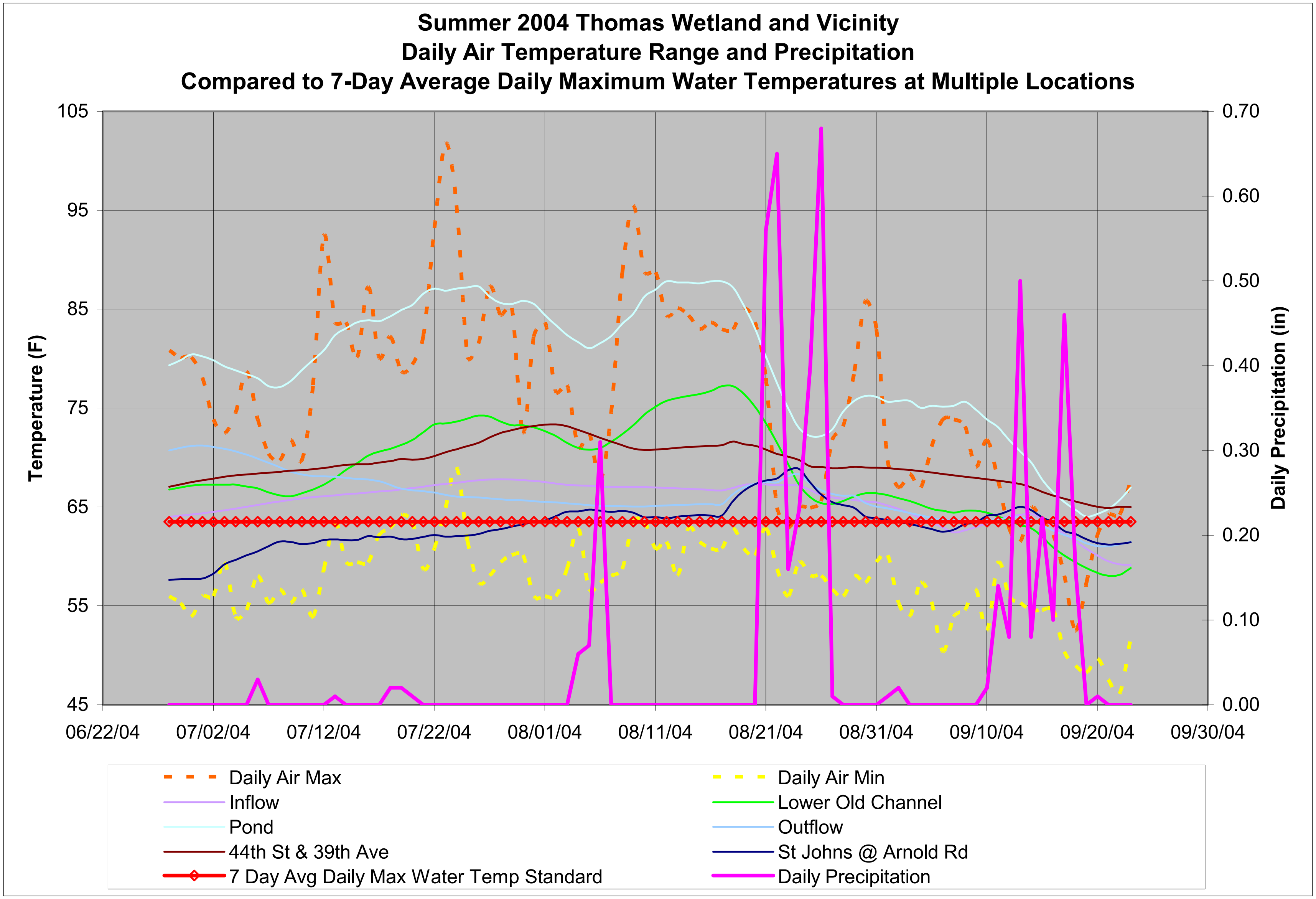

Figure 8 Comparisons of 7-Day Average Daily Maximum Water Temperature.

Summer 2004 Weather Compared to Typical Climate Normals

The summer of 2004 appears to have been mostly somewhat warmer and drier than normal except for a wetter August based on monitoring at Portland International Airport five miles to the southeast of Thomas Wetland (Table 2).

Month In 2004	2004 Average Monthly Temperatures (F)	2004 Departures From Normal Average Monthly Temperatures (F)	2004 Monthly Precipitation Total (inches)	2004 Departures From Normal Monthly Precipitation (inches)
June	65.5	+2.8	1.12	-0.47
July	71.5	+3.4	0.04	-0.68
August	71.5	+3.0	2.68	+1.75
September	62.8	-0.8	1.03	-0.62

Table 2. Preliminary Summer 2004 Departures from Monthly Climate Normals for Portland National Weather Service station at Portland International Airport (calculated based on period from 1941 to 2002).

However, record rainfall on August 21 and 22, 2004 contributed to the monthly precipitation being the fourth most for August since 1941 (NOAA/NWS, 2005). Additionally, June had the fifth warmest average minimum temperature for the month. July had record highs for July 23 and 24 as well as having the fourth warmest average monthly and minimum temperatures for July. August had the warmest average minimum temperature for the month since 1941.

These weather conditions suggest that the summer of 2004 may have been close to a worse case scenario period, based on recent climate records, as far as potential heating impact on the Thomas Wetland. However, possible future climate changes may continue this warming pattern into the future and underscore the importance of mitigating potential heating impacts on water from human activities.

Conclusions and Recommendations

Conclusions

The results from the summer 2004 preliminary temperature study found several important patterns at monitoring stations in the Thomas Wetland facility and the nearby stormwater system. Most of the stations exhibited increasing temperatures as well as increasing diurnal or daily temperature fluctuations through mid-summer which gradually decreased through the end of September. As might be expected due to differences in the monitoring stations' exposure to sunlight and warm winds, temperature maximums and daily variations for the pond and ambient air sites were greater than those for sites located in pipes. The increasing temperatures through mid-summer for the submerged, non-piped stations in the facility can be attributed to both rising air temperatures and decreases in the depth of the overlying water as the pond level dropped. An important exception to the general pattern of increasing temperatures through mid-summer was for the pond's piped outflow site where temperatures decreased then leveled off. The outflow's unique pattern is due to the gradual reduction then lack of flow to it from the pond. The outflow's temperature pattern for mid-summer mostly represents the ambient soil temperatures surrounding the station's manhole location. In general, the recorded temperatures for stations located below ground in manholes reflect a combination of stormwater flow and ambient subterranean air temperatures in the stormwater pipes. The furthest downstream monitoring site, in a manhole located at St. Johns Road and Arnolds Road, had consistently cooler temperatures than any of the other stations. This was probably due to substantial upstream contributions of cool groundwater into the stormwater system and heat exchange with relatively colder ambient soils. This contrasts with the much smaller and warmer flow at the 44th Street / 39th Avenue manhole station where there apparently was very little baseflow contributed by cold groundwater. Substantial drops in temperature across multiple stations coincided only with larger rainfall events when cloudiness produced less solar heating, cooler precipitation fell, and for the stormwater sites there was sufficient contributing rainfall to augment flow. Importantly, during some of the early portions of larger summer rainfall events, especially the record rainfall on August 21, piped stormwater temperatures briefly increased possibly due to contributed runoff previously flowing across warmer impervious surfaces. The summer of 2004 appears to have been mostly warmer and drier than normal except for a wetter August. Thus, as far as water temperature impacts, the study period may be more representative of a historical worse case scenario but also may foreshadow future temperature regimes under ongoing climate warming.

There appears to be substantial heating of the temperature subdued, piped inflowing waters after they enter Thomas Wetland. Interestingly, the temperatures for the lower old channel were between those of the inflow and the pond but remained substantially cooler than the pond's even after the water level dropped. Excluding rainy periods, the pond's temperatures were much warmer than those for any other water monitoring sites. Overall, except for the St. Johns Road at Arnold Road site and a very brief period for the lower old channel, all of the monitoring stations' mid-summer, non-rainy period water temperatures continuously exceeded both the existing 1997 state standard and the state's proposed criteria. This was even true for the piped inflow station's waters but to a lesser extent. These water temperature exceedances continued until mid-September except for periods temporarily cooled by larger summer rainfall events. The only significant exception to this pattern was for the piped St. Johns Road at Arnold Road station which, as noted above, appears to benefit from cooler groundwater contributions and heat exchange with cooler soils surrounding the stormwater system's pipes.

Monitoring Recommendations

The full impact on the accuracy of recorded stormwater system temperatures from the displacement of temperature loggers above their intended water surfaces by high flows is unknown. A more secure temperature sensor / logger attachment mechanism will need to be applied to ensure sustained placement at the intended location for future piped stormwater temperature monitoring. Specifically, future temperature monitoring will need to utilize verified techniques for securely attaching sensors / loggers in the exact intended positions within stormwater pipes so that they can withstand high flows and provide representative data.

Depending on the management concerns for Thomas Wetland, future water quality monitoring may need to include at least continuous recording of stage and possibly even flow at multiple locations upstream, within, and downstream of the facility. Stage monitoring would help track surface water fluctuations, provide information for calculating varying water storage volumes, and delineate periods of outflow to the downstream stormwater system. Additionally, if pollutant loading is of interest especially downstream from the wetland, then continuous flow measurements from a series of stations would also be needed to evaluate attenuation, dilution, and other factors. For example, concurrent secure temperature and flow monitoring within Burnt Bridge Creek in the vicinity of the St. John's stormwater system outflow and within the stormwater system itself would be needed to more accurately and definitively assess possible water temperature impacts. More specifically, from a thermal loading perspective, the potential impact on receiving waters from very high temperatures in low flow portions of a stormwater system could be more than compensated for by only slightly cool but larger flows in another portion of the system.

Increased monitoring would be critical to obtain a more complete understanding of the Thomas Wetland system beyond this study's preliminary temperature investigation. Other flow and water quality questions will need to be addressed by future monitoring efforts.

Thomas Wetland Site Management Recommendations

The temperature pattern for the heavily vegetated lower old channel may resemble the near future patterns in the Thomas Wetland's pond. As the site matures, more submerged and emergent wetland plants will likely become established and may create similar conditions to those currently existing in the lower old channel. Additionally, as shoreline riparian vegetation becomes more established, there may also be more beneficial shading of near shore waters. Therefore, establishing and sustaining a healthy, diverse plant community within the facility will likely not only provide habitat benefits but also help reduce water temperatures while providing other water quality benefits. Additionally, consideration of the long-term benefits of cooling shade, resulting from mature vegetation's possible height and crown shading, should be weighed in selection of future native plants for near shore areas.

Careful selection, establishment, and adaptive management for wetland and riparian plantings will be critical for their survival and water quality benefits given the substantial fluctuations in both Thomas Wetland's pond surface area and depth. As shown in figure 5 and 6, large portions of the pond bottom were exposed for extended periods during the summer of 2004. Therefore, under the site's current configuration, plantings will need to be able to survive both extended periods of inundation and dryness. Some consideration should be given to altering the outflow regime, possibly including holding back more early summer pond storage, to enhance and support beneficial conditions for wetland plants that would otherwise be compromised by very low summer pond levels.

Stormwater System Management Recommendations

This study suggests that the temperature impact of Thomas Wetland on Burnt Bridge Creek appears to be minimal under the precipitation pattern that occurred during the summer of 2004. Portions of the Thomas Wetland's water system exposed to direct sunlight warm considerably during the summer. However, their overall downstream impact is substantially reduced. This results from the overriding benefits of the relatively cooler summer groundwater contributions to the downstream stormwater system, as well as its cool surrounding soils, prior to discharging into Burnt Bridge Creek.

The water temperatures within the Thomas Wetland system often violate state standards during extended hot, dry periods that constitute the summer baseflow conditions. Conversely, only with larger rainfall events do many parts of the Thomas Wetland system briefly cool down to approach the state water temperature standards during the summer. However, due to the low summer water levels in the Thomas Wetland's pond area, substantial storage volume exists for potentially mitigating small to moderate warm, summer stormwater runoff events. In fact, during most of the summer period of maximum heating and stormwater system base flow there may be no surface water discharge at all through the Thomas Wetland outlet. Usually during smaller summer rainfall events some warm stormwater runoff may be collected in Thomas Wetland but not discharged through the outflow. Therefore, until the Thomas Wetland pond level rises to the point of creating outflow discharge, there probably is very little, if any, temperature impact to downstream stormwater systems. When Thomas Wetland's antecedent water level is low, only after fairly severe, sustained, warm rainfall events will there temporarily be warmer discharge from its outflow. Even then, the downstream impacts to Burnt Bridge Creek will be substantially mitigated by intervening cooler groundwater drainage or infiltration and heat exchange with the cool soils surrounding the stormwater pipes. It is important to note that any outflow waters from Thomas Wetland pass through approximately 1.3 miles of below ground stormwater pipe before reaching Burnt Bridge Creek. Therefore, at this time, it does not appear there is a need for Thomas Wetland temperature mitigation.

After Thomas Wetland matures with time, it would be appropriate to reevaluate its potential temperature impacts. This study addressed several specific stormwater temperature issues; however answers to other water quality questions will need additional future monitoring.

References

Christian, Julie. (2003). NE162nd Ave / Thomas Wetland as-built letter to Helen Pressley dated November 19, 2003.

Christian, Julie. (2004). NE162nd Ave / Thomas Wetland monitoring report letter to Anne Robinson dated July 16, 2004.

Clark County Department of Public Works (Gaddis, Phil). June 18, 2002. Final Wetland Mitigation Plan Thomas Wetland. Clark County Department of Public Works. Vancouver, Washington.

Clark County Department of Public Works (Gaddis, Phil). June 19, 2002. Wetland Mitigation Plan NE 162nd Avenue Project. Clark County Department of Public Works. Vancouver, Washington.

Clark County Department of Public Works Water Resources Section (Hutton, Robert). September 2003. Clark County Hydrology Monitoring Project Quality Assurance Project Plan. Clark County Department of Public Works. Vancouver, Washington.

Clark County Department of Public Works Water Resources Section (Hutton, Robert). July 2004. Clark County Thomas Wetland Monitoring Project Quality Assurance Project Plan (Draft). Clark County Department of Public Works. Vancouver, Washington.

National Oceanic and Atmospheric Administration / National Weather Service, Monthly Weather Summary Climatological Report (from NOAA NWS Portland Weather Forecast Office web page), 2005.

Washington State Department of Ecology. Amended July 1, 2003. Water Quality Standards for Surface Waters of the State of Washington Chapter 173-201A WAC. Washington State Department of Ecology. (from Ecology's Web page)

Washington State Department of Ecology. August 2003. Focus on Temperature: Water Quality Standards. Washington State Department of Ecology Water Quality Program, Watershed Management Section. (from Ecology's Web page)